# A Review of Waveform Patterns for Mechanically Ventilated Patients: Constant Flow Versus Decelerating-Flow Waveform Patterns

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Mechanical ventilation has evolved from truly basic devices to sophisticated machines featuring closed-loop logic. The one constant between life support machines of the past and our newer generation ventilators is how the lungs are inflated. Whether the patient is receiving volume-control ventilation or pressure-control ventilation, movement of gas into the lungs is essential. With the advent of computer technology and graphics packages, the gas flow rate can be plotted on a computer screen for analysis. The rate of gas flow and the pattern of flow delivery are as important to mechanical ventilator settings as the tidal volume and inspiratory pressure. In the past, little attention was given to flow waveform patterns, but with more in-depth understanding of mechanical ventilation and patient interaction came a greater appreciation for the flow waveform pattern and the information it presents. Depending on the breath type selected, current mechanical ventilator technology allows the practitioner to select a particular flow waveform pattern to be delivered with each ventilator breath. Although typically not a physician-ordered setting as is tidal volume or inspiratory pressure, the flow waveform pattern can have enormous impact on patient outcomes and reduce complications experienced while on a mechanical ventilator. In this article, we will discuss the more common flow waveforms available on current generation ventilators.

### Flow Waveform Options

*Constant Flow.* Constant flow (Figure 1), also known as a **square** or **rectangle** waveform pattern, is found on most mechanical ventilators—both new and old. Traditional versions of volume-control ventilation utilized a constant flow waveform as the primary flow pattern. The newer generation of ventilators still offers a couple of flow pattern options during volume-control ventilation in addition to constant flow. During breath delivery, inspiratory flow rate instantly rises to a predetermined level and remains constant throughout the inspiratory phase, with the resulting waveform appearing square. Due to this style of flow delivery, a constant flow rate has been shown to produce the shortest inspiratory time compared to other flow patterns. Short inspiratory times allow expiratory times to increase, thus greatly reducing the occurrence of air trapping in patients who are subject to early airway closure.[1] Other benefits of a constant flow waveform pattern include a decrease in mean airway pressure and improvements in venous return and cardiac output.[2]

*Decelerating Flow.* A decelerating flow waveform pattern (Figure 2), also known as **descending ramp**, is a pattern that naturally occurs in patients receiving pressure-control ventilation. Newer generation ventilators will allow practitioners to select this waveform pattern in volume-control modes of ventilation. A decelerating pattern offers the highest level of flow at the start of a breath, when patient flow demand is often greatest.[1] This flow pattern, when used in a pressure-regulated mode of ventilation, may lead to improved patient/ventilator synchrony and provide benefits to those patients who demand high inspiratory flow rates. Additional advantages of this flow pattern include the ability to lower peak inspiratory pressure compared to a constant flow waveform pattern. This may have major implications when peak inspiratory pressures are approaching upper limits.

A decelerating flow waveform pattern also has been shown to increase mean airway pressure. Although on the surface increasing an airway pressure may seem detrimental, mean airway pressure correlates closely with improved lung inflation and oxygenation. Patients receiving mechanical ventilation with a decelerating flow waveform pattern and increases in mean airway pressure have shown an improvement in gas distribution and oxygenation status.[2]Depending on a patient’s condition, there may be disadvantages to using a decelerating flow waveform pattern. An increase in mean airway pressure has been shown to cause a decrease in venous return and cardiac output. Hemodynamic stability and recent head trauma should be considered when choosing the decelerating flow waveform pattern because of the secondary increase in mean airway pressure.[2] Other disadvantages include a potential reduction in expiratory time when compared to the constant flow waveform pattern. Because there is a linear reduction in gas flow toward baseline during a decelerating flow waveform pattern, the inspiratory phase is often extended compared to breaths delivered with a constant flow waveform pattern. An increase in inspiratory time will cause expiratory time to decrease and I:E ratio to increase and may be intolerable to patients who require extended expiratory times. Careful attention toward the development of air trapping should be observed in patients who need reduced I:E ratios.[3]

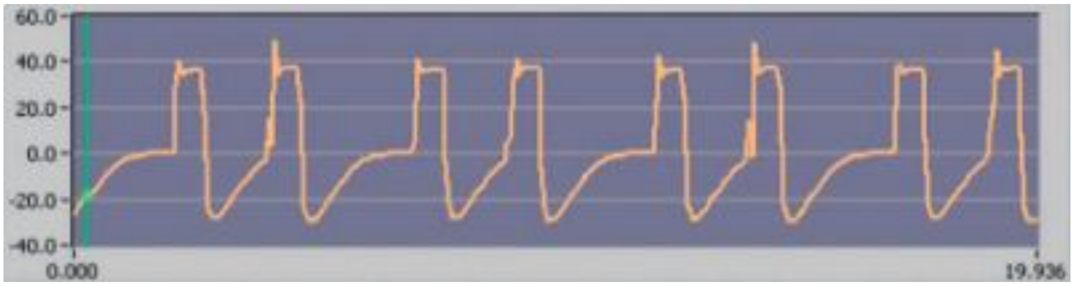


***Figure 1. Constant flow waveform pattern***

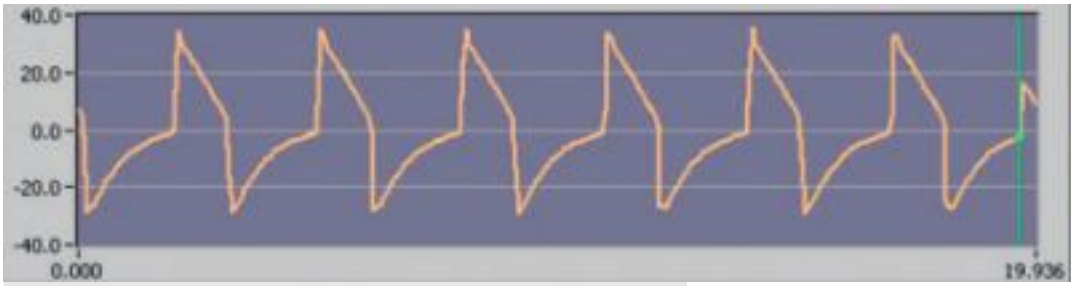
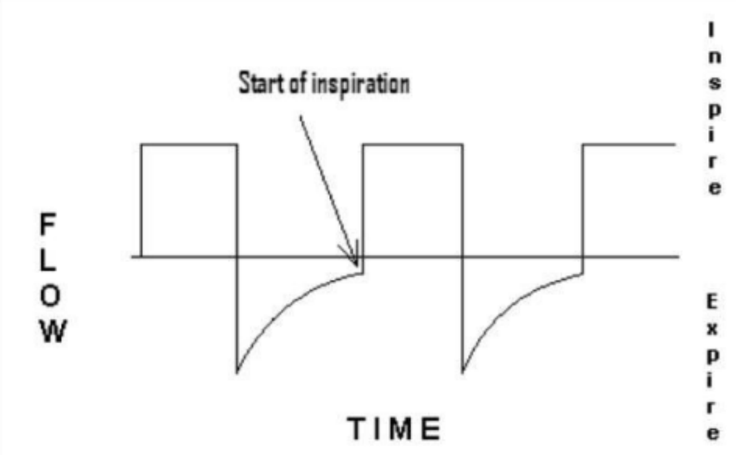


*Figure 2. Decelerating flow waveform pattern*



### Effects of Changing Flow Pattern

There are multiple ways to end or cycle a breath: pressure cycling, time cycling, volume cycling, and flow cycling. Adjusting the flow waveform pattern can have different effects when ventilating with a time-cycled breath compared to a volume-cycled breath. In a time-cycled breath, the inspiratory time is set and used as the primary criteria for ending the breath. When changing from a constant flow waveform pattern to a decelerating pattern, the peak-flow rate will automatically adjust upward. The loss of a constant flow rate will require the ventilator to use a higher peak-flow rate to achieve the preset tidal volume during the set inspiratory time. Although peak-flow rate increases, there is no change in I:E ratio and expiratory time; inspiratory time is set directly. This could be beneficial for patients who require an extended expiratory time in addition to the benefits of a decelerating flow waveform pattern.[2]

Volume or flow cycling means the breath will terminate once a preset volume or flow is reached. Inspiratory time is not set directly and will vary based on these criteria. The impact of a flow waveform pattern change will be different when using a volume-cycled breath compared to the changes with a time-cycled breath mentioned previously. Changing from a constant to a decelerating flow waveform pattern in a volume-cycled breath will lead to changes in inspiratory time, expiratory time, and I:E ratio. Peak flow remains constant in this example; however, inspiratory time will increase.[2] The increase in inspiratory time will shorten expiratory time and increase I:E ratio. The change in inspiratory time relates to the relationship between volume, flow rate, and time. In order to deliver the set tidal volume using the set peak flow rate and the decelerating flow waveform pattern, the inspiratory time has to change. As addressed earlier, the decelerating flow waveform pattern results in a linear decrease in flow rate, whereas a constant flow waveform pattern results in a steady flow rate throughout inspiration. The decreasing flow rate pattern leads to an extended inspiratory time.

### Benefits of a Decelerating Waveform Pattern

Previous research has outlined the benefits of a decelerating flow pattern seen in neonatal and pediatric patients. The research revealed that modes of ventilation using a decelerating flow waveform pattern may be safely used in neonates and may contribute to a lower incidence of complications compared to a pressure preset intermittent mandatory ventilation mode.[3,4] Similar research revealed that a decelerating flow waveform pattern caused a 19% decrease in a patient's peak inspiratory pressures without impacting hemodynamics, arterial oxygenation, or $CO_2$ removal compared to results in traditional volume-control ventilation using constant flow waveform pattern.[5]
Other research directly compared the effects of a constant and decelerating waveform pattern in children with congenital heart disease.[6] The investigation utilized a pretest/posttest design. Patients were placed in volume-control mode with a constant flow pattern, then switched to PRVC mode (decelerating flow pattern) with 30 minutes of results recorded in each mode. Research results indicated that a decelerating flow waveform pattern provided a statistically significant decrease in peak inspiratory pressures compared to a constant waveform pattern with the same settings. Additionally, assessments on each patient's work of breathing revealed that there was a decrease in work of breathing when utilizing a decelerating flow waveform pattern.[6] Likewise, a decelerating waveform pattern has been shown to reduce dead space ventilation and alveolar-arterial gradient for oxygen.[7,8] Rappaport et al[9] reported that patients ventilated with a decelerating flow waveform pattern had a decrease in peak inspiratory pressure and length of intubation with an increase in static lung compliance when compared to a constant flow waveform pattern.

### Conclusion

The flow rate and flow waveform pattern must be correctly set and carefully adjusted to suit each individual patient. For example, faster peak inspiratory flow rates may benefit patients diagnosed with COPD by providing extended expiratory time and reducing the risk of auto-PEEP.[1] In contrast, some patients—such as those diagnosed with ARDS—will benefit from an extended inspiratory phase.[1] Adjusting the flow waveform pattern can help individualize the breath to help both conditions.

Although patients may be safely ventilated utilizing a constant flow pattern, the decelerating flow pattern does provide other benefits in addition to minimizing pressures. A decelerating flow waveform pattern has been shown to reduce peak inspiratory pressures, dead space, and alveolar-arterial gradients while increasing mean airway pressures and improving patient to ventilator synchrony. Ultimately, a reduction in complications associated with mechanical ventilation will depend on the practitioner's ability to make individual adjustments in care based on a patient's condition and disease process. A decelerating flow waveform pattern is simply another tool practitioners can use to effectively aid in reducing complications.

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